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Spinal cancer research advancements with Imaging, Molecular Profiling and Precision Treatment

23 October 2026 | Views | By Dr Sewanti Limaye, Director of Medical & Precision Oncology at Sir H.N. Reliance Foundation Hospital

The future of spinal oncology research should go beyond new technologies towards evidence-based integration



Spinal tumours involve a unique interaction of oncology, neurosurgery, radiology and radiotherapy. Clinical significance of spinal tumours goes beyond just growth of the neoplasm since even fairly small tumours may affect spinal cord, nerve roots and vertebral bones. Thus, advances in biology, diagnostics and local therapy of tumours have brought a change in the field of spinal oncology. An important goal of the modern approach is not only the tumour control but also its functional sparing.

Primary spinal tumours and metastases are two different groups of spinal neoplasms, which have different biological features, prognosis and therapy. Correct classification of these tumours is crucial for planning of the optimal therapy. Primary spinal tumours include lesions developing from vertebral bone tissue, cartilaginous or other supportive tissues, while metastases develop at the site of another primary tumour.

Advanced imaging: Beyond anatomical diagnosis

Magnetic resonance imaging (MRI) remains one of the key methods of evaluation of spinal tumours due to the fact that it allows detailed visualization of vertebral marrow, extra-marrow invasion, spinal cord lesion and adjacent soft tissues. In case of multifocal metastatic lesions, whole spine MRI is necessary. T1-, T2-weighted and STIR images allow characterizing the lesion and its relation to the neural structures.

Imaging not only detects the presence of a tumour but also provides other information for management decisions. High-resolution T2 axial MRI allows epidural spinal cord compression assessment in order to make decision on surgical decompression and radiation therapy. The imaging results need to be correlated with neurological assessment, stability and overall cancer status of the patient. In case of metastatic spinal cord compression, prompt diagnosis and investigation are critical due to irreversible neurological damage.

New developments in advanced imaging, quantitative radiomics, and artificial intelligence will potentially further enhance lesion characterisation, segmentation, treatment planning and response evaluation. Nevertheless, these technologies should undergo validation studies before being used for making clinical decisions.

Molecular profiling: Precision oncology of spinal disorders

In case of metastatic spinal lesions and when the primary tumour is genetically defined, molecular profiling becomes relevant. Histopathology and immunohistochemistry define the type of the tumor, and next-generation sequencing may identify genetic mutations that can be targets of systemic therapy.

In case of metastasis, the molecular features of the primary lesion determine treatment choice (targeted therapy, immunotherapy, etc()). Biopsy of a spinal mass lesion is indicated in selected cases where there is diagnostic uncertainty, an unusual presentation, or if a change in management would occur.

The value of combined pathological and molecular classification in primary bone tumours and primary soft tissue tumours of the spine is evident. Tumour genomics continues to develop further disease classifications and potentially reveal targets for treatment. However, not all genomic changes are relevant to therapy, and information obtained in other tumour settings cannot be directly applied to spinal disease.

Precision Radiotherapy: Improved Tumour Local Control

Stereotactic body radiotherapy (SBRT) is an important advancement in treating spinal metastases. SBRT involves administration of very precise, high-dose radiation with minimal exposure of the spinal cord and other critical organs around the tumour.

SBRT offers durable local control in the appropriately selected patient even for some tumours which are otherwise relatively resistant to standard radiotherapy. Treatment choices are made based on tumor histology, history of radiotherapy, extent of epidural disease, spinal instability and dose constraints achievable to the neural elements. Proper planning is crucial in order to prevent potential adverse events including radiation myelopathy and vertebral compression fractures.

Combining SBRT with systemic therapy is an additional important topic for investigation. With the advent of targeted treatments and immunotherapies that prolong survival in some types of cancer, local control of spinal metastases becomes increasingly important. There is a need for prospective investigations in order to determine appropriate sequencing, patient selection and clinical outcomes.

Minimally invasive surgery and multidisciplinary decision making

Changes in the surgical approach are also ongoing. Instead of attempting maximal resection of the tumor in all patients, specific interventions focus on decompression of neural elements, stabilization of the spine and separation of the tumor from the spinal cord to enable delivery of SBRT after surgery. Minimally invasive techniques like percutaneous fixation and vertebroplasty may help to achieve the goal in some patients.

NOMS concept is an efficient tool in this process. It is based on the level of neurological dysfunction, responsiveness of tumour to various treatment approaches, stability of spine, and disease burden of a particular patient. Such a strategy emphasizes the importance of coordinated decisions of medical oncologists, spine surgeons, radiation oncologists, radiologists, and pathologists.

Future directions in spinal oncology research

The future of spinal oncology research should go beyond new technologies towards evidence-based integration. Some of the key priorities include validation of AI-assisted imaging technology, better molecular classification of tumours, identification of biomarkers of response, optimisation of SBRT and sequence of systemic therapy, as well as the creation of prospective registries with defined neurological and quality-of-life endpoints.

Access to advanced imaging technologies, molecular diagnostics, precise radiotherapy, and specialised surgery is also crucial, especially in heterogenic health care systems.

In the end, progress in research on spinal cancers should be evaluated not only by imaging response and local tumour control but also by neurological function preservation, spine stabilization, and proper treatment. In this case, precision oncology represents a promising concept provided that new technologies can be successfully integrated into clinical practice.

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